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Use practices of antimicrobials and other compounds by shrimp and fish farmers in Northern Vietnam

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ABSTRACT

Aquaculture production is increasing in Vietnam, but is hampered by frequent disease outbreaks and widespread use of various compounds used to treat the fish and shrimp. The objective of this study was to analyse factors influencing farmer use practices of antimicrobials and other compounds by a questionnaire and observational survey conducted with 60 whiteleg shrimp (*Litopenaeus vannamei*) and 25 fish farmers in three coastal provinces in Northern Vietnam. Personnel in 22 shops distributing feed and chemicals for aquaculture were interviewed about their advice on sale to the farmers. Results showed that 20 different antimicrobial products were used for disease prevention and treatment in shrimp and marine fish culture. Banned products used included chloramphenicol, enrofloxacin and malachite green. Cage fish farmers said they purchased antimicrobial tablets readily available at a local pharmacy and sold for human use. Chinese traders were the main drug suppliers to the shrimp farmers in Quang Ninh and others provinces. Their products were sold with labels and product information written in Chinese only. Farmers appeared to have little awareness and concern about the disease aetiology when applying specific antimicrobials. Up to 50% of the shrimp farmers used up to 20 different disinfectants, e.g. chlorine-based compounds, to disinfect water in storage ponds, often without knowledge of the type of disinfectants and their mode of action. A variety of probiotics, vitamins, minerals and herbal extracts were routinely used by mainly shrimp farmers to enhance shrimp immunity. There is an urgent need to provide aquaculture farmers access to diagnostic and independent disease control advisory services and quality medicated feed, since the current indiscriminate use of antimicrobials and other compounds are inefficient, costly, and hazardous to the aquatic animal and farmer's health, the environment and food safety.

1. Introduction

Aquaculture in Vietnam has developed rapidly and provides income and quality protein for national and overseas consumers, e.g. 328,000 tonnes of whiteleg shrimp (*Litopenaeus vannamei*) and 1.22 million tonnes of striped catfish *(Pangasianodon hypophthalmus)* were produced in 2015 (MARD, 2016). The rapid development and intensification of culture practices have been associated with serious disease outbreaks and economic losses. Tiger shrimp (*Penaeus monodon*) in particular, but also whiteleg shrimp culture have been experiencing major viral disease problems, e.g. caused by White Spot Syndrome Virus, Yellow Head Virus, and Taura Syndrome Virus (Dhar et al., 2004; Lightner, 2011; Hasson et al., 1995 and Sittidilokratna et al., 2008). Recently, Early Mortality Syndrome, also called Acute Hepato-Pancreatic Necrosis Syndrome, has been associated with *Vibrio parahaemolyticus* infections, and caused up to 100% mortality in post larvae shrimp (20–30 days of age) (FAO/MARD, 2013; Tran et al., 2013). Mariculture production, e.g. floating cages, of high value fish species have shown a dramatic increase along the coast and around islands in Vietnam due to increasing demand from Vietnamese consumers. Fish species cultured in marine cages include cobia (*Rachycentron canadum*), seabass (*Lates calcarifer*), and grouper (*Epinephelus coioides*). As experienced by the shrimp industry, mariculture farmers are also experiencing major disease problems, e.g. bacterial diseases caused by *Vibrio* spp., *Streptococcus* spp. and *Flexibacter* spp. (Phan et al., 2006).

Ideally any therapeutic treatment of an infectious disease should be based on a correct diagnosis including identification of the pathogen involved before any treatment takes place. The reality for most aquaculture farmers in less developed countries like Vietnam however, is

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quite different with limited availability and access to such diagnostic services (Phu et al., 2015a; Li et al., 2016). Farmers seem to base their choices of disease prevention and treatment measures on previous experiences, anecdotal advice from shops selling and distributing antimicrobials and other chemicals, and less often taking advice from veterinarians who do not have the capacity and knowledge to provide diagnostic services (Li et al., 2016; Phu et al., 2015b). However, there is limited knowledge on how farmers perceive and diagnose diseases and what determines their choice of type of treatment, e.g. use of antimicrobials. The main Asian countries practicing aquaculture as yet do not have efficient monitoring systems to register use of antimicrobials and other chemicals nor do the individual farmers. However, there is increasing evidence that certain aquaculture producers are using substantial amounts of antimicrobials and other compounds for disease and pond management. Thuy and Loan (2011) estimated that both numbers and amounts of veterinary drugs and chemicals used in Vietnamese shrimp culture have increased significantly over the last 10 years. Tai (2012) reported more than 30 types of antimicrobials used in shrimp culture and more than 130 different antimicrobial products used in all types of Vietnamese aquaculture. Most studies on drug and chemical usage in aquaculture in Vietnam have been conducted in the Mekong Delta region (Phu et al., 2015a; Rico et al., 2013) and little is known about such use practices elsewhere in the country.

Quality and use of antimicrobials and other veterinary compounds in aquaculture are meant to be assured and approved by different authorities, e.g. in Vietnam by the Ministry of Agriculture and Rural Development (Phu et al., 2015b; MARD, 2014). In 2012, a total of 2913 products were registered for use in Vietnamese aquaculture, including 813 so-called veterinary drugs (Tai, 2012; MARD, 2014). The approval of such high numbers of products for use in aquaculture is highly resource demanding and it was recently documented that a number of antimicrobial products used in Vietnamese striped catfish culture were of inferior quality (Phu, 2015b). Furthermore, veterinary drugs may also be imported illegally from neighbouring countries. Effective quality assurance and regulatory authoritative systems of antimicrobial and other compound usage in aquaculture is essential to ensure farmers' access to quality drugs, allowing for effective disease treatment and the provision of safe foods to consumers with no antimicrobial residues.

The objective of this study was to obtain information about the main factors determining the use of antimicrobials and other compounds in disease and farm management in whiteleg shrimp and marine finfish aquaculture in three coastal provinces in Northern Vietnam. Based on this knowledge, we discuss the main challenges faced by the farmers and propose how these may be addressed to develop responsible use of antimicrobials and other compounds in aquaculture assuring effective prevention and treatment of diseases and the safety of aquaculture products.

2. Materials and methods

2.1. Study sites and aquaculture farmers

The study was conducted in Hai Phong, Quang Ninh and Nghe An provinces in main aquaculture districts as registered by the local Departments of Agriculture and Rural Development (Fig. 1). Around Cat Ba island off the coast of Hai Phong city, 12 intensive cage farms stocking more than 25 marine fish/m^3 were randomly selected to represent typical marine cage culture farms operating around the island. At the time of the study, a total of 571 families were operating their own floating fish farms around Cat Ba island as their main income generating activity with cage numbers ranging from 15 to 50 cages per farm. Workers on the farms were all family members. In addition, 13 family-operated farms were selected practicing on-land culture in earthen ponds (Thuy Nguyen district, Hai Phong city) with brackish water intake from the coast during high tide. Feed consisted of wild-caught marine trash fish and was freshly prepared by the individual farmers.

In Quang Ninh province, intensive whiteleg shrimp is cultured totalling 2200 ha, mainly practiced around Mong Cai city close to the Chinese border. Shrimps are raised in earthen ponds (0.64–15 ha) with slopes of the pond dykes often being lined with plastic. Fifteen intensive farms with a stocking density of more than 80 shrimp/m^3 and 15 semi-intensive (25–30 shrimp/m^3) farms owned and managed by families were selected for interviews. A few larger shrimp farms owned by local Vietnamese companies were also operating, but unwilling to participate in the study. In Nghe An province, 30 households operating intensive culture of whiteleg shrimp were randomly selected from a list of 1053 farmers provided by the local Department of Aquaculture as registered in 2012. Characteristics and livelihood conditions of the family-operated farms studied were similar in the two provinces.

A questionnaire and observational survey were conducted from August to September 2012 with the aquaculture farmers in the selected provinces. In addition, a number of shops selling feed, chemicals and other items to aquaculture farmers were visited for questionnaire interviews and observations. A small follow-up study was conducted from May to July 2014 visiting the shrimp farmers to obtain information about their economic losses due to diseases.

2.2. Farmer interviews and observational survey

A questionnaire was developed for face-to-face interview of farm owners. On-farm observations by the interviewers were done to supplement the information collected during the interviews. Both interviews and on-farm observations were conducted in Hai Phong, Quang Ninh and Nghe An provinces by the first author of this paper together with two trained assistants. The following subject areas were addressed in the questionnaire: general information on aquaculture management practices, i.e. name of farmer, culture area, cultured species, culture system, feeding practices; type and seasonality of diseases and associated economic losses; types and use practices of antimicrobials and other compounds (i.e. disinfectants, probiotics, herbal products, vitamins and minerals). The term antimicrobial is used throughout the manuscript and includes antibiotics and chemically synthesized compounds used to treat bacterial diseases. Where possible, direct observations and records were made of the type and storage conditions of feed and chemicals present at the farm together with medication practices.

2.3. Feed and chemical shops

Feed, chemicals and other compounds used by aquaculture farmers in Northern Vietnam are provided and distributed by so-called feed and chemical shops that are typically located in district towns. These premises are owned by Vietnamese families except a few shops owned by Chinese. Products sold may be produced by Vietnamese companies or produced outside Vietnam and then imported by local companies supplying the products to the shops. It was not possible to obtain information about the total number of shops in the study areas, but according to information from the local Departments of Agriculture and Rural Development between 20 and 30 shops operated in each of the three provinces. Some shrimp farmers also operated their own small shops selling feed and chemicals to nearby shrimp farms. All shops were registered by provincial and district government authorities and were occasionally inspected, e.g. to check on appropriate and safe storage conditions of chemical products.

Based on information provided by the farmers during the interviews, two larger shops in Hai Phong city were selected that sold products to brackish water fish and shrimp farms in Thuy Nguyen district. In both Quang Ninh and Nghe An provinces, 10 feed and chemical shops were visited that provided products to the provincial shrimp farmers. During visits to the shops, information was collected about types of antimicrobials, chemicals and other compounds sold,

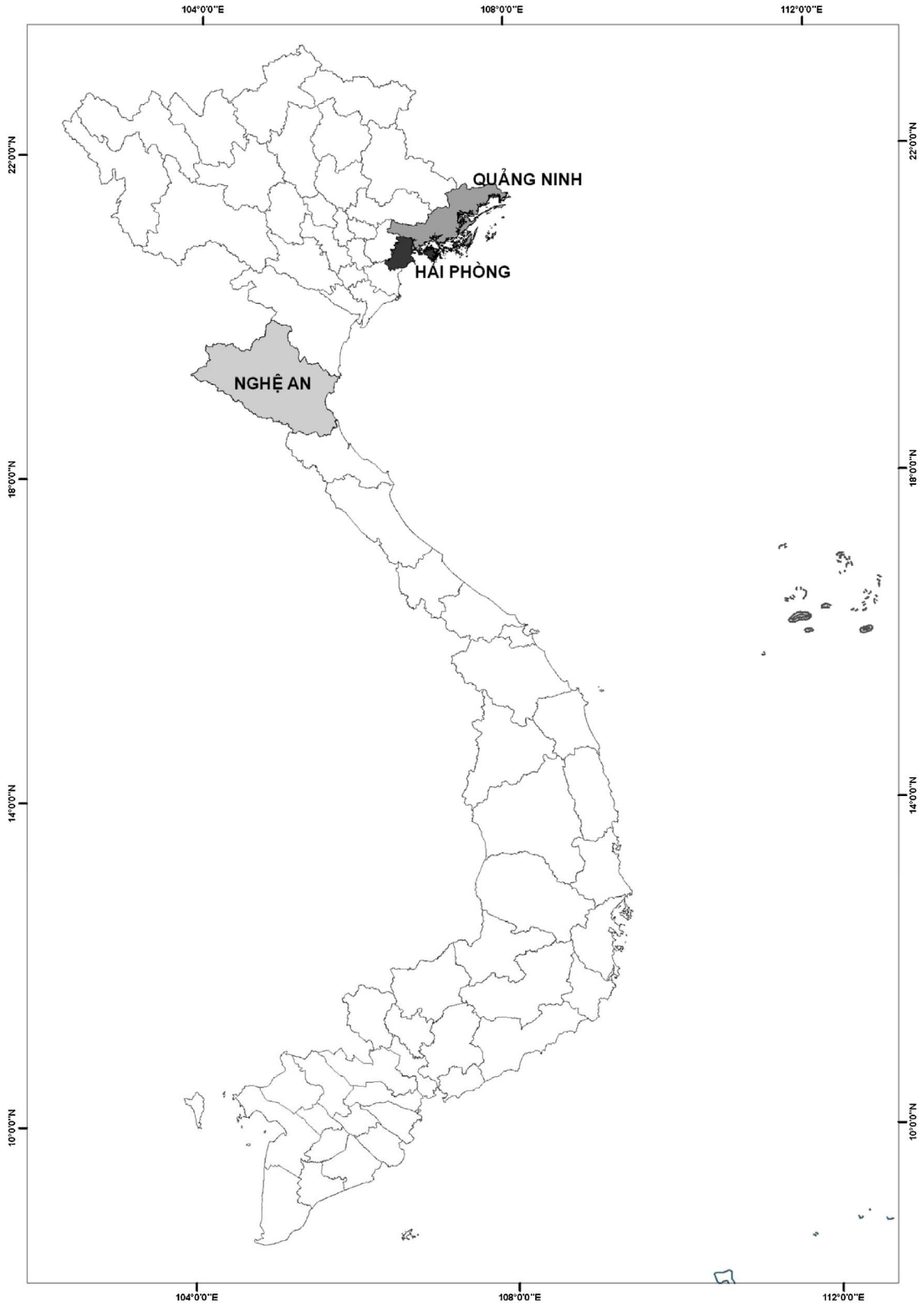

Fig. 1. Map of three study provinces.

instructions on use provided on labels and type of advices that the staff provided to farmers on correct use of sold products.

2.4. Data analysis

Data and information from the questionnaire interviews were quality checked before entered into Microsoft Excel and subsequent descriptive data analysis. Based on product label information, chemical and antimicrobial products were divided into: 1) antimicrobials; 2) disinfectants (disinfection and treatment of water and pond sediment); 3) probiotics; 4) vitamins and minerals; 5) herbal extracts and 6) unidentified products. The data were analysed using tabular and

Table 1
Type and number of products used in whiteleg shrimp (Quang Ninh and Nghe An provinces) and marine fish farms (Hai Phong province).

Product type	No of products used		
	Hai Phong (n = 25)	Quang Ninh (n = 30)	Nghe An (n = 30)
Disinfectants (water and pond sediment)	13 (68%)[a]	19 (100%)	41 (100%)
Antimicrobials	17 (64%)	1 (3%)	8 (33%)
Probiotics	6 (28%)	12 (73%)	30 (93%)
Vitamins and minerals	12 (32%)	10 (40%)	29 (93%)
Herbal extracts	3 (20%)	3 (23%)	10 (56%)
Others	4 (16%)		5 (16%)

[a] The figure in brackets indicates the percentage of farms that used a particular product type.

descriptive statistical methods.

3. Results

The marine cage culture farmers around Cat Ba Island obtained antimicrobials and other compounds mainly from one local pharmacy in Cat Ba town selling medicines for humans.

In Quang Ninh province, the shops visited included three large shops operated by Chinese owners that seemed to be major providers to the shrimp farmers. A particular focus was therefore to collect information and evaluate the role of these Chinese shops as suppliers of products to the Vietnamese shrimp farmers.

Results showed that a diverse range of 184 different products were being used in shrimp and marine fish farming in the three provinces. The type and number of products used are shown in Table 1.

3.1. Diseases and use of antimicrobials

Generally, the shrimp and marine fish farmers were not able to identify or at best had limited knowledge about the etiological agent (i.e. pathogen) causing a particular disease. Occasionally farmers reported disease outbreak or mortalities in order to obtain external advice for disease diagnosis from staff and representatives of feed and chemical shops distributing. Farmers described a particular disease based on symptoms, behaviour and previous experience, e.g. marine fish farmers reported disease symptoms such as slow movements, gill rot, big belly, bleeding and black body, ulcerated mouth, skin ulcers ("scabies disease"), "jump head first into cage wall", and whirling head. Symptoms and names for shrimp diseases included "jump to water surface and sudden death", red or pink body, shrunk or swollen liver, white spot, "sudden and early death with no cause". Mortalities in whiteleg shrimp typically occurred within 21–28 days of culture after the post larvae were stocked into the ponds. Types and frequency of disease and mortalities of fish in the cages varied depending on species and size.

The Provincial Departments of Agriculture and Rural Development (DARD) usually has a unit with aquaculture expertise, but their focus is mainly on aquaculture production aspects and less on outreach activities to prevent and control diseases. Under DARD, there is a unit responsible for aquatic animal health. At district level, animal health officers may visit aquaculture farms to give advice during disease outbreaks or when ponds are stocked with fingerlings. However, the number of aquatic animal health personnel is limited and farmers interviewed stated that government staff rarely visited their areas and often they arrived when fish or shrimp mortalities were already high. One to two annual training courses were reported to be held by government officials, but little information is provided about prudent use of antimicrobials and other compounds to prevent or treat diseases. Farmers therefore mainly based their choice of antimicrobial and other chemical usage on their previous experiences.

A total of 20 different antimicrobial products were used for disease prevention and treatment in shrimp and marine fish culture (Table 2). Thus, farmers based their choice of which type of antimicrobial to purchase mainly on their own and other farmer's experiences, with some advice also taken from sellers at the feed and chemical shops. Antimicrobials were used both prophylactically and for treating disease outbreaks in marine cage and brackish pond fish culture and included fluoroquinolones, phenicols and tetracyclines (Tables 1 and 2); however, only one shrimp farmer in Quang Ninh province reported using antimicrobials (oxytetracycline). Tetracyclines were also the main class of antimicrobials used by shrimp farmers in Nghe An province (Table 2).

In Hai Phong city, two large feed and chemical shops provided antimicrobials and other compounds to the land-based brackish water farms culturing seabass and tilapia (*Oreochromis niloticus*). The marine cage culture farmers purchased antimicrobials from local feed and chemical shops in their home district of Thuy Nguyen, but due to long distance and infrequent visits to their home district the majority of antimicrobials were therefore purchased as tablets from a local pharmacy on Cat Ba Island. Farmers stated that these human drugs had a lower price and, because sold for human use, were more effective compared with antimicrobials sold in the shops catering aquaculture farmers. When visiting the pharmacy, farmers described the symptoms of the diseased fish and the seller then recommended which antimicrobial should be used for treatment often with a reference to antimicrobials that were effective in treating human diseases, e.g. rifampicin and chloramphenicol. The tablets, which normally are sold for treatment of human diseases, were crushed and the powder mixed (typically with bare hands) with trash fish before being minced by a grinding machine and subsequently thrown into the cages. The dose to be administered to the fish was calculated similar to the recommended dosage to humans, i.e. number of tablets used daily to treat an adult weight (60–70 kg) were used as a reference. The duration of treatment was equal to that declared for humans, i.e. 5–7 days. The shrimp

Table 2
Antimicrobials used in whiteleg shrimp and fish farms in three provinces of Northern Vietnam.

	Hai Phong (n = 25)		Quang Ninh (n = 30)	Nghe An (n = 30)
Antimicrobial (class)	Marine fish cages (n = 12)	Brackish fish ponds (n = 13)		
Ampicillin (beta-lactams)	1			1
Rifampin (also referred to as rifampicin) (rifamycins)	2	1		
Chloramphenicol (phenicols)	1	2		
Enrofloxacin (fluoroquinolones)		1		
Lincomycin (lincosamides)	1			
Tetracycline, doxycyline, oxytetracycline (tetracyclines)	2	4	1	6
Ciprofloxacin (fluoroquinolones)	1			
Oxytetracycline/neomycin (tetracyclines/aminoglycosides)	2	3		3
Sulfamethoxazole/trimethoprim (sulphonamides)		1		
Unidentified[a]	1	3		2

[a] Products did not have a label, but farmers reported product to be an antimicrobial.

farmers typically top-coat the feed pellets with a mix of antimicrobial powder dissolved in fresh water. This was done by adding the antimicrobial solution with a cup into a feed container after which the farmers mixed the antimicrobial solution and feed pellets with their hands. It was not possible to obtain information about dosage and duration of treatment for the limited number of shrimp farmers in Quang Ninh and Nghe An provinces that used antimicrobials. All of 85 marine fish and shrimp farmers (100%) handled antimicrobials and prepared the medicated feed without any protective measures, e.g. gloves or masks, often with direct hand contact.

It was difficult to obtain accurate figures on how much money farmers spent on different products used to prevent and control diseases and for general aquaculture management because none of the fish and shrimp farmers visited kept records. Farmers seemed little aware of how to keep such records, and of the fact that keeping track of antimicrobial usage could help them monitor expenses in general, as well as potentially benefit their farm management. However, the farmer interviews revealed that such costs and economic losses due to diseases were high and significantly negatively affected the farmeŕs profit margins. In Quang Ninh province, five shrimp farmers were reported recently to have lost 80–140 million Vietnamese Dong/ha (3640–6360 US$/ha) because of shrimp diseases and high mortalities. Whereas more than one third (27/55) of farmers in Nghe An (11/30 farms) and Hai Phong (16/25 farms) provinces reported economic losses from 20% to 100% of their overall operational costs (incl shrimp, fish, feed, chemicals, etc) due to diseases.

3.2. Chemicals used for disinfection, water and soil treatment

A total of 55 different compounds were reported to be used to improve water and pond sediment quality and for general management of biosecurity in shrimp farms. Quicklime (CaO) was applied by 52/60 shrimp farmers from Quang Ninh and Nghe An province during pond preparation as a disinfectant, to kill invasive species of fish and crustaceans, to adjust and buffer pH, and to fertilize plankton growth. Farmers termed the latter effect as “making colour of water”. CaO was also applied following rain events to increase pH. Chlorine (e.g. benzalkonium chloride) and less often iodine-based compounds were used by most shrimp farmers to disinfect farm equipment (including nets, pumps and aerators) and disinfect the pond before post larvae shrimp were stocked, but also during disease outbreaks to kill pathogens. Dosages applied were 30–55 ppm (30–55 g/m3). However, farmers did not report that they adjusted dosages of chlorine based on water quality characteristics, e.g. content of organic matter. Zeolite was used by 34/60 shrimp farmers to remove ammonia and other toxins from pond water, but also as a pond fertilizer. Eleven out of 13 fish farmers in Hai Phong used CaO, 3/13 farmers used chlorine and 2/13 farmers used zeolite for pond water disinfection. While on Cat Ba island, none of the cage fish farmers used disinfectants, but cleaned cage nets with high pressurized marine water and then air dried nets between fish crops. Both marine and brackish fish farmers used malachite green (6/25), $KMnO_4$ (1/12), formaldehyde (1/12), iodine (1/12) and methylene green (1/12) in water baths to treat parasitic diseases.

The intensive shrimp farmers in Nghe An province all used disinfectants with an average of 12.3 different products used per farm with up to 22 different products used at one single farm. Farmers used and combined several different products to disinfect water in shrimp ponds as well as in reservoirs without specific knowledge on mode of action of the individual products, e.g. several farmers applied products with different trade names, but containing the same active compounds. It was noted that some farmers stated that they had experienced that such applications had a negative impact on the presence of beneficial microorganisms and could stimulate shrimp moulting.

3.3. Use of probiotics, vitamins, herbal extractions and unknown substances

The use of probiotics, vitamins and minerals among shrimp farmers was common and substantial, e.g. 100% of farmers in Nghe An province and 22/30 farms in Quang Ninh province mixed such compounds into feed to improve feed digestibility, but also to control outbreaks of intestinal diseases. They were also added into the pond water throughout the production cycle even when no diseases occurred. The use of these compounds was strongly promoted by the feed and chemical shops and farmers stated they used the compounds although they were not always sure about their effectiveness. Several farmers stated that they also used probiotics because they were not harmful, e.g. no residues accumulated in the treated shrimp like with antimicrobials. More recently farmers seemed reluctant to change pond water due to fear of introducing pathogens; consequently use of probiotics seems to have increased to control problems caused by the accumulated organic matter. Based on declared information on product labels, probiotic bacterial strains used as feed supplements included at least two of the following genus/species: *Bacillus* spp., *Lactobacillus* spp., and *Saccharomyces cerevisiae*; while *Rhodococcus pseudomonas*, *Rhodococcus spirillum*, *Nitrosomonas* spp. and *Nitrobacter* spp. were the main bacteria used to control water quality. Product labels did not allow an identification of the particular bacterial strains included. Fish farmers in Hai Phong (6/25) used probiotics less often, mainly in brackish fish pond culture to control water quality.

About half of all farmers (48/85) in the three provinces applied a total of 21 products containing vitamins and minerals. Vitamin C was commonly used daily by shrimp farmers and some brackish fish farmers mixed vitamin C and B1 into the feed. Shrimp farmers stated that they used vitamin C and a variety of mineral products to maintain good pond water quality, to protect shrimp from heat shock during warm weather, and as feed additives to increase immunity and resistance during disease outbreaks. Vitamins and minerals were often applied simultaneously with antimicrobials, herbs and other compounds. About 23% of the shrimp farmers in Quang Ninh province and 56% in Nghe An province used herbal extracts such as *Solanum hainanense*, *Phyllanthus urinaria* L, *Adenosma glutinosum* and garlic as preventive measures to enhance the immunological status of shrimp. Herb products were purchased from feed and chemical shops, but also produced locally by the farmers. For example, farmers in Nghe An province prepared an extract by boiling several local herbs that were known to cure liver diseases in humans and mixed it with feed pellets that were fed daily to the shrimp mainly affected by so-called hepatopancreas disease. On several occasions farmers stated to have used products where they did not have any knowledge or information about the actual compound contents. Products used by shrimp farmers in Quang Ninh province often had labels written in Chinese and farmers therefore depended on information provided by the shop owners about the product content and how it should be used.

3.4. Feed and chemical shops

During visits to the feed and chemical shops in the three provinces, all shop owners informed that they had to pay directly for all feed, drugs and chemical products purchased from different suppliers. Large shops invested up to five billion Vietnamese Dong (VND) equalling 250,000 USD on the purchase of the different products in stock. In the past, shop owners said that they could obtain credit from their suppliers and pay for products purchased typically after the shrimp harvest when farmers were able to pay the shops. Due to financial constraints for the farmers, mainly caused by losses due to diseases, farmers now had to pay immediately when purchasing products as shop owners had experienced that farmers were not able to pay for their products if provided credit. Some large product suppliers had sale representatives in the shops who also acted as technical assistants providing advisory services free of charge. The sale representatives furthermore recommend to farmers which products should be used for disease control

Table 3
Type and number of products reported sold by feed and chemical shops to whiteleg shrimp and fish farmers in the three study provinces.

Product type	Hai Phong (n = 2)	Quang Ninh (n = 10)	Nghe An (n = 10)
Disinfectants (water and pond sediment)	4	20	36
Antimicrobials	6	7	3
Probiotics	1	23	34
Vitamins and minerals	1	19	40
Herbal extract		1	7
Unidentified products		5	3

and aquaculture management. Such advice was also provided during visits to the farm if the company saw the farmers as a potential key-account customer. However, all shops gave some kind of advice on the use of their products. Shops often obtained their products from one or a few large suppliers from which they received bonuses according to the quantity of products sold. Farmers stated that they choose shops based on previous positive experiences and recommendations from other farmers. Based on observations, a total of 196 products were sold in the shops in three provinces including disinfectants; antimicrobials; probiotics; vitamins and minerals; herbal extracts and a number of unidentified products (Table 3).

A total of 14 antimicrobial products belonging to the classes of phenicols, tetracyclines, fluoroquinolones, sulphonamides and rifamycins were sold by the shops (Table 4). Six out of 14 products were sold in Quang Ninh province by three Chinese owned shops in Mong Cai city which sold a variety of different products. All product labels in these shops were in Chinese and when label text was translated it appeared that the type of antimicrobial was not declared. Some antimicrobials, e.g. oxytetracycline and doxycycline, were stored in large plastic containers, e.g. 25 kg. The Chinese shop owners had been trading aquaculture products in Mong Cai city for nearly 20 years. Farmers typically described the symptoms of the diseased shrimp and the shop owner then instructed the farmers on which products to buy and how they should be used. Farmers were generally little aware and concerned about the type of products purchased and, just like the shop owners, saw little need for product labels in Vietnamese. The prime concern for the farmer was that the drugs could solve their disease problems. The Chinese shop owners also stated that they sold and could deliver products for farmers in other provinces, even in Southern Vietnam.

A total of 54 different disinfectants were sold to shrimp farmers in Hai Phong, Quang Ninh and Nghe An province to improve water and pond sediment quality and for general biosecurity management at their farms (Table 3). Chlorine (e.g. benzalkonium chloride) was most commonly sold (15/20 shops), followed by zeolite (6/20 shops). A total of 56 probiotic products and a similar number of vitamin products and minerals were sold mainly to shrimp farmers in particular in Nghe An province (Table 3). Vitamin C was commonly sold (11 different products in Quang Ninh; four products in Nghe An, and one product in Hai Phong). Eight different herbal products were sold in Nghe An (8/10 shops) and Quang Ninh province (1/10 shops). In Hai Phong city, only two large feed and chemical shops sold products for fish and shrimp farmers (Table 3).

Table 4
Antimicrobials reported sold by feed and chemical shops to whiteleg shrimp and fish farmers in the three study provinces.

Antimicrobial (class)	Hai Phong (n = 2)	Quang Ninh (n = 10)	Nghe An (n = 10)
Chloramfenicol, florfenicol (phenicols)	1	3	1
Doxycycline, oxytetracycline, tetracycline, (tetraxyclines)	4	9	
Enrofloxacine (fluoroquinolones)	1	3	
Sulfamethoxazol (sulphonamides)	1		
Sulfamethoxazole/trimethoprim (sulphonamides) Rifamycine (rifamycins)			1
Sulfamethoxazole/trimethoprim (sulphonamides)		1	
Enrofloxacin/erythromycin (fluoroquinolones/macrolides)			1

4. Discussion

Our study documents that fish and shrimp farmers in these three provinces in Northern Vietnam are facing serious disease problems that significantly affect their production and economy and that they therefore have a regular and high use of a variety of antimicrobials, disinfectants, probiotics, vitamins, minerals and herbs. Although the main part of data was collected in 2012, follow-up visits to the study areas do not indicate any major changes in aquaculture management practices. All fish and shrimp farmers in this study had little knowledge about the aetiology and causative agents of particular diseases affecting their fish or shrimp as well as on the correct use of such compounds. Farmers also had limited access to independent scientific-based advisory services. Therefore, they take decisions on what antimicrobials and other chemicals to use based on own experiences and advice from neighbour farmers, from sales staff of local feed and chemical shops and from company representatives visiting the farms. When farmers visited the shops, they typically described symptoms of their diseased fish or shrimp based on which the seller would then recommend an antimicrobial and/or other compounds for treatment. Often the shop sellers recommended a combined treatment with an antimicrobial and probiotics.

We did not study particular pathogens associated with the described disease symptoms, but the main pathogens associated with diseases in brackish pond and marine cage fish culture include viral nervous necrosis (VNN; betanodavirus) disease and different types of bacterial diseases causing ulcers (Phan et al., 2006). Main shrimp diseases are of viral origin and include white spot disease caused by white spot syndrome virus (WSSV) and Taura syndrome (picorna virus). Bacterial diseases include acute hepatopancreatic necrosis disease (AHPND; *Vibrio parahaemolyticus*) and other types of vibriosis. External parasitic diseases (e.g. flukes (monogeneans), sea lice and leech) mostly occur in hatcheries and nurseries of both marine and freshwater fish. Thus, the current antimicrobial use practices of farmers are ineffective because farmers often treat common viral and parasitic disease with antimicrobials despite the fact that such treatment does not have any direct effect. Furthermore, diseased fish and shrimp are not examined by veterinarians or other professionals to establish a diagnosis and knowledge about the disease aetiology to support correct treatment.

It is unlikely that current antimicrobial use practices of fish and shrimp farmers will lead to sufficient antimicrobial concentrations in the diseased aquatic animals needed for effective therapeutic treatment. Farmers prepared their own medicated feed for shrimp and fish by mixing the antimicrobial powder or solution with clean water without acknowledging that some antimicrobials are hydrophobic, e.g. rifamycin, trimethoprim and sulfamethoxazole (Khalil et al., 2008). The practice of applying antimicrobial solutions to feed pellets and subsequent mixing by hands is likely to cause large variations in antimicrobial concentration in the feed. This was confirmed in a recent study by Phu et al. (2015a) where three batches of enrofloxacin-medicated feed prepared by catfish farmers in Southern Vietnam using the same methodology as farmers in this study, were found to contain 106 ± 10.1 mg/kg, 49.9 ± 13.3 mg/kg, and 39.8 ± 8.6 mg/kg feed, respectively. Similarly, the crushing and mixing of antimicrobial tablets for human treatment into trash fish by the cage fish farmers at Cat Ba island will lead to large variations in antimicrobial concentrations in the feed. Furthermore, shrimp feed pellets will in contrast to medicated

feed provided to fish not be immediately consumed, but rather the shrimp will eat the pellets at the bottom of the pond over a prolonged time period during which the added antimicrobial will dissolve into the pond water, e.g. ampicillin and oxytetracycline. Phu et al. (2015b) also documented that antimicrobial products commonly used in catfish aquaculture often contain significantly lower antimicrobial concentrations than declared on the labels. Thus, there is an urgent need for farmers to access quality antimicrobial products and medicated feed, e.g. feed mills should be urged and allowed to produce such feed which will also reduce significantly farmer's direct physical contact with antimicrobials when preparing medicated feed and the associated health risks.

The application in aquaculture of antimicrobials intended for human use is worrisome. Marine cage fish farmers at Cat Ba island stated that they purchased and used antimicrobial tablets such as rifampicin and chloramphenicol from the local pharmacy on the island. Neither sellers at the pharmacy nor farmers seemed aware that the formulation of antimicrobial tablets and recommended dosage for humans are not suitable to obtain an adequate therapeutic antimicrobial concentration in fish. Furthermore, the use of rifampicin is particularly worrisome as this drug is essential for treatment of highly resistant human bacterial infections, e.g. tuberculosis, and human exposure to chloramphenicol residues in fish meat can have potentially fatal side-effects such as aplastic anaemia and hypersensitivity (Cunha, 2001). Accordingly, there is a worldwide ban of chloramphenicol use in livestock and aquaculture.

Farmers were generally reluctant to keep records of their antimicrobial and other compound use. This is also the experience from different initiatives promoting farmers to keep records as required by recently introduced certification schemes, e.g. VietGAP. In VietGAP. These schemes require farmers to keep records on their management practices and all compounds used, including antimicrobials, as well as occupational health safety measures (MARD, 2015). Follow-up studies, e.g. qualitative, are needed to get a better understanding on why farmers do not want to keep such records.

It is surprising that ciprofloxacin is still allowed for use in aquaculture. Enrofloxacin was banned for aquaculture use in 2012 (MARD, 2012), but both drugs are fluoroquinolones (enrofloxacin is oxidatively de-ethylated into ciprofloxacin). The use of antimicrobials and chemicals in Vietnamese aquaculture is regulated by the Ministry of Agriculture and Rural Development (MARD) and currently 23 compounds are banned and 33 compounds approved (MARD, 2003). Approved antimicrobials include ampicillin, amoxicillin, ciprofloxacin, colistin, erythromycin, florfenicol, sulphonamides, tetracyclines, and trimethroprim many of which are also important human drugs. Despite the ban, we found one feed and chemical shop in Hai Phong and two shops in Quang Ninh (Table 4) selling products containing enrofloxacin. Although farmers did not report any use of colistin, it should be noted that the emergence of multidrug-resistant Gram-negative bacteria have sparked a renewed interest in the polymyxins to treat multidrug-resistant *Pseudomonas aeruginosa*, *Acinetobacter baumannii* and *Klebsiella pneumonia* infections in humans and polymyxins like colistin are now seen as the only available effective antibiotics to treat such infections (Gu et al., 2014). The recent reports of transferable resistance to colistin found in livestock in China is therefore particularly worrisome (Liu et al., 2016). Polymyxins should no longer be used in livestock or aquaculture and colistin should be removed from the list of approved antimicrobials for use in Vietnamese aquaculture. Malachite green was used by 6/25 farmers at Cat Ba island to treat parasite and fungal diseases despite this compound being banned internationally for use in aquaculture due to its carcinogenic properties (Srivastava et al., 2004).

Farmers were often not able to differentiate between antimicrobials and other chemicals and termed all of these "drugs". Observations made around the ponds and in household's sheds during visits to shrimp farmers in Nghe An province often revealed empty bags and containers of antimicrobials despite farmers' statements in the interviews that they did not use antimicrobials. Also, farmers in certain areas visited seemed aware that some antimicrobials were banned by the Vietnamese authorities; although they did not know the particular banned antimicrobials. This uncertainty may have made some farmers reluctant to report antimicrobial usage during interviews. Shrimp farmers in Quang Ninh province were generally not able to differentiate antimicrobials from other compounds used and it is therefore likely that the antimicrobial use was underestimated. Clearly, farmers need to be informed about which antimicrobials are approved for use in aquaculture. It seems that the local Departments of Aquaculture should regularly provide such updated information to farmers, e.g. as part of training courses.

There is a need to make the approval procedures of antimicrobial products for the Vietnamese market more simple and less resource demanding. A very high number (> 100 products) of antimicrobial products are marketed in Vietnam and the approval of these are demanding for companies and authorities, e.g. some companies are experiencing that product approvals may take several years. It also appears that companies on some occasions have changed the composition of their product, e.g. by removing and adding new antimicrobials, without seeking new approval (Phu et al., 2015b; MARD, 2003). Harmonization of approval procedures between Asian and other countries, e.g. as is the practice within the European Union, should also be considered.

Our results clearly show that the current disinfectant use of shrimp farmers is substantial, but practices are ineffective and likely to negatively impact the microbial pond ecology and overall shrimp health. Chlorine-based compounds were used to disinfect water in reservoir ponds (30–55 g/m^3) before it was pumped into the shrimp ponds and some farmers used more than 20 different disinfectants in combination, often without knowledge of the type of disinfectants and their mode of action. The effectiveness of treatment with chlorine-based compounds is questionable as water in shrimp ponds contains high concentrations of organic matter and to which these disinfectants are readily adsorbed. Chlorine-based compounds are not effective in removing biofilm on pond lining material, paddle wheels, and other equipment (Boyd and Massaut, 1999). In fact, pond disinfection eliminates a large part of microorganisms in the pond. After refilling ponds, surviving microorganisms (including fast growing bacteria such as *Vibrio parahaemolyticus*, which is the cause of early mortality syndrome in shrimp) multiply using available nutrients in sediment and water, with little competition from other microorganisms (De Schryver et al., 2014).

Most probiotic products declared the bacterial genus and occasionally also the species, but no information was provided about the specific strain included. A recent study of probiotics used in shrimp culture in Southern Vietnam showed that commonly used probiotics quite often did not contain the declared bacterial species (Uddin et al., 2015). Herbal use by shrimp farmers to enhance the immunological status of the shrimp was widespread and followed the Vietnamese tradition of using herbs to treat human diseases. For example, some farmers stated that particular herbs used to treat liver problems in people, i.e. *Phyllanthus urinaria* L, were also used to treat hepatopancreas type of disease in shrimp. There seems to be increasing scientific evidence that herbs may be effective alternatives to antimicrobials in treatment of shrimp diseases, e.g. viral diseases (Sivasankar et al., 2015), but more research is needed before herbal treatment should be promoted for disease treatment.

In conclusion, our study shows that fish and shrimp farmers in the three study provinces are continuously experiencing disease problems that cause severe economic loses. Farmers routinely apply a variety of antimicrobials, disinfectants, probiotics, minerals and other compounds to combat such diseases. There is an urgent need to strengthen and improve the capacity of existing government institutions to provide advice on disease prevention and control, e.g. establishing effective national disease diagnostic surveillance systems, and access to quality products, but also to identify new ways, e.g. involving both public and

private partners. Alternatives to antimicrobial disease treatments should be investigated through more research on impact of improved farm biosecurity (including special pathogen free production of shrimp larvae and fingerlings), use of vaccines, probiotics and traditional herbal treatments. Also, certification schemes to promote the prudent use of antimicrobials and other compounds should be considered.

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